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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04R 9/06, 9/04, 7/16 | A1

(11) International Publication Number: **WO 00/47013**

(43) International Publication Date: 10 August 2000 (10.08.00)

(21) International Application Number: PCT/GB00/00333

(22) International Filing Date: 7 February 2000 (07.02.00)

(30) Priority Data:
9902585.0 6 February 1999 (06.02.99) GB

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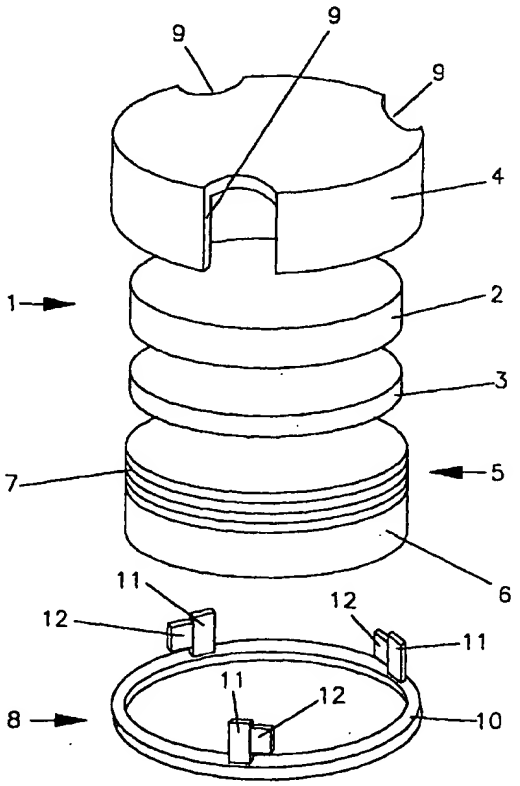
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: VIBRATION EXCITER FOR CREATING BENDING WAVE VIBRATION

(57) Abstract

A moving coil vibration exciter (1) for exciting a resonant diaphragm comprising a magnet assembly defining an annular gap (2), a voice coil assembly (5) arranged in the annular gap, a mounting member (8) by which the exciter is mounted on the diaphragm and to which the voice coil assembly is fixedly attached, and a resilient suspension (12) on the mounting member and coupled to the magnet assembly to permit axial movement of the voice coil assembly (5) in the annular gap, the arrangement being such that the footprint of the resilient suspension is contained within that of the mounting member or is co-extensive therewith.



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VIBRATION EXCITER FOR CREATING BENDING WAVE VIBRATION

DESCRIPTION

TECHNICAL FIELD

The invention relates to vibration exciters. More particularly the invention relates to moving coil vibration exciters for creating bending wave vibration in bending members to produce an acoustic output. Such vibration exciters can thus form the drivers in resonant panel loudspeakers. Resonant panel loudspeakers are described in International patent application WO97/09842 and such have come to be known as distributed mode (DM) loudspeakers (DML).

BACKGROUND ART

It is known from EP-A-0 160 478 to provide a moving coil pistonic cone loudspeaker drive unit comprising a component part build ring incorporated with the voice coil

assembly and adapted to interconnect the rear suspension spider with the coil former and to connect the pistonic cone diaphragm to the voice coil.

In known moving coil vibration exciter designs intended for use in driving resonant panel loudspeaker, a magnet assembly may be connected to a voice-coil assembly by way of a flexible suspension member positioned between a flange-like extension of the magnet cup and the outside diameter of the coil. This flexible member can in known manner be made from cloth formed into a corrugated section, or any suitable flexible or resilient material.

A disadvantage of this arrangement is that the proximity of the flange to the resonant panel creates a cavity which causes the enclosed air to generate cavity modes in the audible frequency range. Such cavity modes will radiate from the open periphery of the flange, and can give rise to unwanted acoustic output, which might be difficult to absorb. Some improvement can be gained by sealing-off the region between the pole piece and the panel by having no gap in the region of the voice-coil, but the outer portion of the flange still generates cavity modes in the audible frequency range.

Voice coil alignment in the annular gap of the magnet assembly is critical for performance and, apart from loss of efficiency caused by large air gaps, there is evidence that even very slight voice coil misalignment or lack of concentricity causes rocking in the gap which is relatively unrestrained in single suspension exciter designs.

At least as important in the design of efficient exciters is the gap size which cannot easily be reduced unless lateral freedom of the voice coil is tightly restricted. Foam rubber suspension systems give equal vertical and lateral movement so increasing the stiffness laterally to retain good coil alignment increases suspension stiffness in the operating plane of movement which limits low frequency extension.

It is clear that in some applications miniature exciters need a suspension system that allows free movement in and out of the air gap but very tight restraint in other directions to allow the gap size to be reduced and the efficiency increased.

Suspension in two planes will ensure pistonic motion with a minimum tendency to rock. However, this basic requirement is perhaps subtly altered for DML operation. The need for the exciter to "ride" the bending wave reflections it creates requires the suspension at the back of the voice coil (behind the magnet) to be laterally more compliant than the suspension in front of the magnet so that the side to side movement at the rear of a voice coil "riding" a reflected bending wave does not try to push the magnet cup sideways. This same point requires that the front suspension element should be as close to the resonant (DML) panel as possible.

DISCLOSURE OF INVENTION

According to the invention a moving coil vibration exciter

for exciting a bending wave, e.g. resonant, diaphragm comprising a magnet assembly defining an annular gap, a voice coil assembly arranged in the annular gap, a mounting member by which the exciter is mounted on the diaphragm and to which the voice coil assembly is fixedly attached, and a resilient suspension on the mounting member and coupled to the magnet assembly to permit axial movement of the voice coil assembly in the annular gap, the arrangement being such that the footprint of the resilient suspension is contained within that of the mounting member or is co-extensive therewith. Preferably the footprint of the resilient suspension means is contained within that of the magnet assembly. The vibration exciter may be inertial.

The magnet assembly may comprise an inner pole piece and an outer cup-like pole piece, both pole pieces being coupled to a magnet. The outer pole piece may have a periphery formed substantially without a flange. The periphery of the outer pole piece is tapered to have a sharp termination.

The mounting member may be co-extensive with the outer pole piece. The mounting member may be annular or disc-like.

The suspension may be disposed entirely in the thickness of the wall of the outer pole piece. The suspension may couple between the inner pole piece and a mounting member fixed inside the voice coil assembly. Alternatively the suspension may couple between the cup and the mounting member.

The resilient suspension may be in the form of blocks of flexible material fixed between axial extensions of the mounting member and cut-outs in the outer pole piece. Alternatively, the suspension may comprise a resilient member disposed on the axis of the disc-like mounting member and the inner pole piece. In a further embodiment, the resilient suspension may comprise an annular spring member. The annular spring member may further comprise arms the free ends of which are fixed to the outer periphery of the outer pole piece.

The outer pole piece may comprise a detachable disc-like back and a tubular part. The exciter may further comprise a second resilient suspension displaced axially from the said suspension and coupled between the voice coil assembly and the magnet assembly. The second suspension may be disposed in a recess defined between the back and the tubular part of the outer pole piece. The second suspension may be a resilient annular suspension and may further be disposed in a circumferential groove on the magnet.

The voice coil assembly preferably comprises a voice coil wound on a coil former. The suspension may comprise electrical contacts to connect the voice coil assembly with a power supply to energise the voice coil assembly.

By introducing the suspension in a plane at right angles to the panel, the need for a flange on the magnet cup to support the suspension is removed, which prevents the remaining air being trapped. These embodiments will reduce any potential flange area, which, if present, could

given undesirable cavity modes.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:-

Figure 1 is an exploded perspective view of a first embodiment of inertial moving coil vibration exciter for driving bending waves into a panel loudspeaker;

Figure 1a is a perspective view of the vibration exciter of Figure 1;

Figure 2 is a second embodiment of inertial moving coil vibration exciter for driving bending waves into a panel loudspeaker;

Figure 2a is a cross-sectional side view of the exciter of Figure 2;

Figure 2b is a cross-sectional side view, generally corresponding to that of Figure 2a, but showing a modified suspension arrangement;

Figure 3 is a cross-sectional side view of another embodiment of inertial moving coil vibration exciter for driving bending waves into a panel loudspeaker;

Figure 4 is a cross-sectional side view of another embodiment of inertial moving coil vibration exciter for driving bending waves into a panel loudspeaker;

Figure 5 is a cross-sectional side view of another embodiment of inertial moving coil vibration exciter for driving bending waves into a resonant panel loudspeaker;

Figure 6 is a cross-sectional side view of another embodiment of inertial moving coil vibration exciter for driving bending waves into a panel loudspeaker, and

Figure 7 is a cross-sectional side view of another embodiment of inertial moving coil vibration exciter for driving bending waves into a panel loudspeaker.

BEST MODES FOR CARRYING OUT THE INVENTION

In Figures 1 and 1a there is shown an inertial moving coil vibration exciter (1) for exciting bending wave vibration in a panel, e.g. a resonant panel of the kind described in WO97/09842, to form a loudspeaker, comprising a magnet assembly having a magnet (2) sandwiched between an inner disc-like pole piece (3) and an outer cup-like pole piece (4) to define an annular gap (not shown), a voice coil assembly (5) having a tubular coil former (6) on which is wound a coil (7), and a suspension and mounting assembly (8) to which the voice coil is rigidly attached to unite the magnet assembly and the voice coil assembly to allow axial movement of the voice coil in the annular gap and by which the exciter is mounted on a resonant panel (not shown) to be excited.

As shown the cup (4) is formed with three equi-spaced slots as cut-out portions (9) in its periphery and the assembly (8) comprises a mounting or build ring (10) having substantially the same inner and outer diametrical dimensions as that of the peripheral wall of the cup (4). The ring (10) is formed with three equi-spaced axially

extending projections or posts (11) which form lugs to which are attached rectangular resilient suspension blocks (12), e.g. of a rubber-like material the arrangement being that the lugs (11) and suspension blocks (12) are adapted for reception in the slots (9) in the cup (4) and the suspension blocks (12) are attached to the walls of the slots by sides opposite to those by which the blocks (12) are attached to the lugs.

In this way the suspension is contained within the thickness of the wall of the cup so that it is not necessary to provide the cup with a flange at its periphery so that the problem stated above is mitigated.

The exciter embodiment of Figure 2 and 2a is generally similar to that of Figure 1 in that the exciter (1) comprises a magnet assembly having a magnet (2) sandwiched between an inner disc-like pole piece (3) and an outer cup (4) to define an annular gap (20), a voice coil assembly having a tubular coil former (6) on which is wound a coil (7) and a suspension and mounting assembly (8). However, in this case the suspension comprises a spring device (13) in the form of a ring (14) e.g. of stainless steel fixed to the mounting ring (10) and portions of which define three equi-spaced curved spring arms (15), the free ends (16) of which are fixed to the periphery of the cup. As will be appreciated, the spring device (13) is depicted schematically in Figure 2a.

As in Figures 1 and 1a, the voice coil assembly (5) is rigidly fixed to the ring (10) so that the spring ring (14)

forms a suspension between the voice coil assembly and the cup of the magnet assembly. As shown, the arms (15) are at the outer diameter of the ring (14) but it will be appreciated that the arms (15) may either be at the inner or at the outer diameter of the spring ring (14).

Alternatively as shown in Figure 2b, a spring suspension element can provide a suspension between the inner pole piece (3) and a disc (30) fixed to the coil former (6). The spring (14) locates concentrically on the pole piece (3) e.g. by forming a hole (not shown) in the spring and in which a protrusion (not shown) on the pole piece (3) can locate. This alignment is transferred to the voice coil (7) by locating the spring concentrically inside the voice coil former (6) and by making it a tight fit in the former. The exciter construction would therefore be self-aligning and the lateral suspension compliance would be small enough to allow the air gap to be relatively small.

Figure 3 shows a further embodiment of exciter (1), similar to that of Figure 2b and comprising a cup (4) made in two parts to have a detachable disc-like back (4a) and a tubular part (4b) together defining a recess (23) to allow space for a spider suspension (17) at the back of the voice coil (7) to facilitate a two plane suspension with different lateral compliances between front and back planes.

This design lends itself to two additional features, which fit in with the easy self-aligning assembly, namely:-

(1) the pole piece spring suspension (13) can be made to bayonet lock onto a build disc (30) to allow easy assembly and disassembly of the exciter, and

(2) the voice coil connections can be linked to electrical contacts (16) on the build disc 30 which in turn would contact conductive pads (not shown) on the loudspeaker panel (not shown) in an exciter mount contact system as the exciter contacts the panel surface. This would eliminate wiring from the delicate voice coil wire to external cable or tabs and improve balance of the magnet assembly. Further it would eliminate cable runs to or across the panel because the conductors could be embedded or encapsulated in the panel skin as thin copper plate or as a conductive paint coating.

Acceptance of the principle of assembling the magnet cup from pieces opens the possibility of very compact integrated suspension systems especially for small exciters. The illustration in Figure 4 is of an exciter (1) generally as described in Figures 2b and 3 and shows how two circumferential slots (not shown) in the magnet (2) allow a simple double plane suspension system using flat flexible washers (19) which fit between the magnet (2) and the former (6). This takes advantage of the wider annular gap (24) between magnet (2) and the side of the tubular cup part (4b). Note that both the pole piece (3) and the backplate (4a) are recessed to centre the magnet (2) so that the whole exciter including voice coil (7) is self-aligning. In this embodiment, the front suspension is

provided by a soft foam block (18) concentrically positioned on the disc (30) and pole piece (3).

A variation of the exciter of Figure 4 is shown in Figure 5, and uses a standard unmodified, that is to say ungrooved, magnet (2). In this embodiment, the cup is assembled from three self-aligning pieces (4a), (4b) and (4c) e.g. of steel, which separate at the places where suspension recesses are machined allowing pre-assembly of the suspension rings (19) onto the voice coil former (6). In this case an upper tubular section (4c) is used to terminate the cup and the termination (21) is sharp to improve acoustic cavity effects and the true air gap (20) is created only where it is needed to align with the pole pieces.

The exciter arrangement shown in Figure 6 is generally similar to that of Figure 5 and lends itself to smaller assemblies but could also be used on larger exciters where very firm lateral alignment deriving from the distance between front and back suspension would help in the design application. The maximum excursion of the voice coil into the cup must be defined to prevent the pole piece front support from hitting the panel. In practice a foam buffer might be used at this point.

As shown in Figure 7 the simplicity of the design of the Figure 6 embodiment of exciter can be further enhanced by sacrificing some magnet area and fitting an annular foam ring rear suspension (22) around the circumference of the magnet (2) and contacting the inner surface of the former

(6). Correct selection and tolerancing of the foam would allow the voice coil assembly (5) to be simply pushed on and self align at the rear of the assembly. The front of the voice coil assembly (5) would be aligned by the pole piece suspension (18) which is concentrically positioned on the disc (30) and pole piece (3). The disc (30) is supported by mounting ring (10).

CLAIMS

1. A moving coil vibration exciter for exciting a bending wave diaphragm comprising a magnet assembly defining an annular gap, a voice coil assembly arranged in the annular gap, a mounting member by which the exciter is mounted on the diaphragm and to which the voice coil assembly is fixedly attached, and a resilient suspension on the mounting member and coupled to the magnet assembly to permit axial movement of the voice coil assembly in the annular gap, the arrangement being such that the footprint of the resilient suspension is contained within that of the mounting member or is co-extensive therewith.

2. An exciter according to claim 1, wherein the magnet assembly comprises an inner pole piece and an outer cup-like pole piece, both pole pieces being coupled to a magnet.

3. An exciter according to claim 2, wherein the outer pole piece has a periphery formed substantially without a flange.

4. An exciter according to claim 3, wherein the periphery of the outer pole piece is tapered to have a sharp termination.

5. An exciter according to any one of claims 2 to 4, wherein the mounting member is co-extensive with the outer pole piece.

6. An exciter according to any one of claims 2 to 5, wherein the suspension is disposed entirely in the thickness of the wall of the outer pole piece.

7. An exciter according to any preceding claim, wherein the mounting member is annular.

8. An exciter according to any one of claims 2 to 6, wherein the suspension couples between the inner pole piece and a mounting member fixed inside the voice coil assembly.

9. An exciter according to any one of claims 2 to 8 when dependent on claim 2, wherein the resilient suspension is in the form of blocks of flexible material fixed between axial extensions of the mounting member and cut-outs in the outer pole piece.

10. An exciter according to any one of claims 1 to 7 wherein the mounting member is disc-like.

11. An exciter according to claim 10 when dependent on claim 2, wherein the suspension comprises a resilient member disposed on the axis of the disc-like mounting member and the inner pole piece.

12. An exciter according to any preceding claim, wherein the resilient suspension comprises an annular spring member.

13. An exciter according to any preceding claim, wherein the resilient suspension comprises electrical contacts to connect the voice coil assembly with a power supply to energise the voice coil assembly.

14. An exciter according to any preceding claim, comprising a second resilient suspension displaced axially from the said suspension and coupled between the voice coil assembly and the magnet assembly.

15. An exciter according to claim 14, wherein the second suspension is a resilient annular suspension.

16. An exciter according to claim 15, when dependent on claim 2 wherein the second suspension is disposed in a circumferential groove on the magnet.

17. An exciter according to any one of claims 2 to 16 when dependent on claim 2, wherein the outer pole piece comprises a detachable disc-like back and a tubular part.

18. An exciter according to claim 17 when dependent on claim 14 wherein the back and the tubular part define a recess to house the second suspension.

19. An exciter according to any preceding claim, wherein the exciter is inertial.

20. An exciter according to any preceding claim, wherein the footprint of the resilient suspension is contained within that of the magnet assembly.

Figure 1

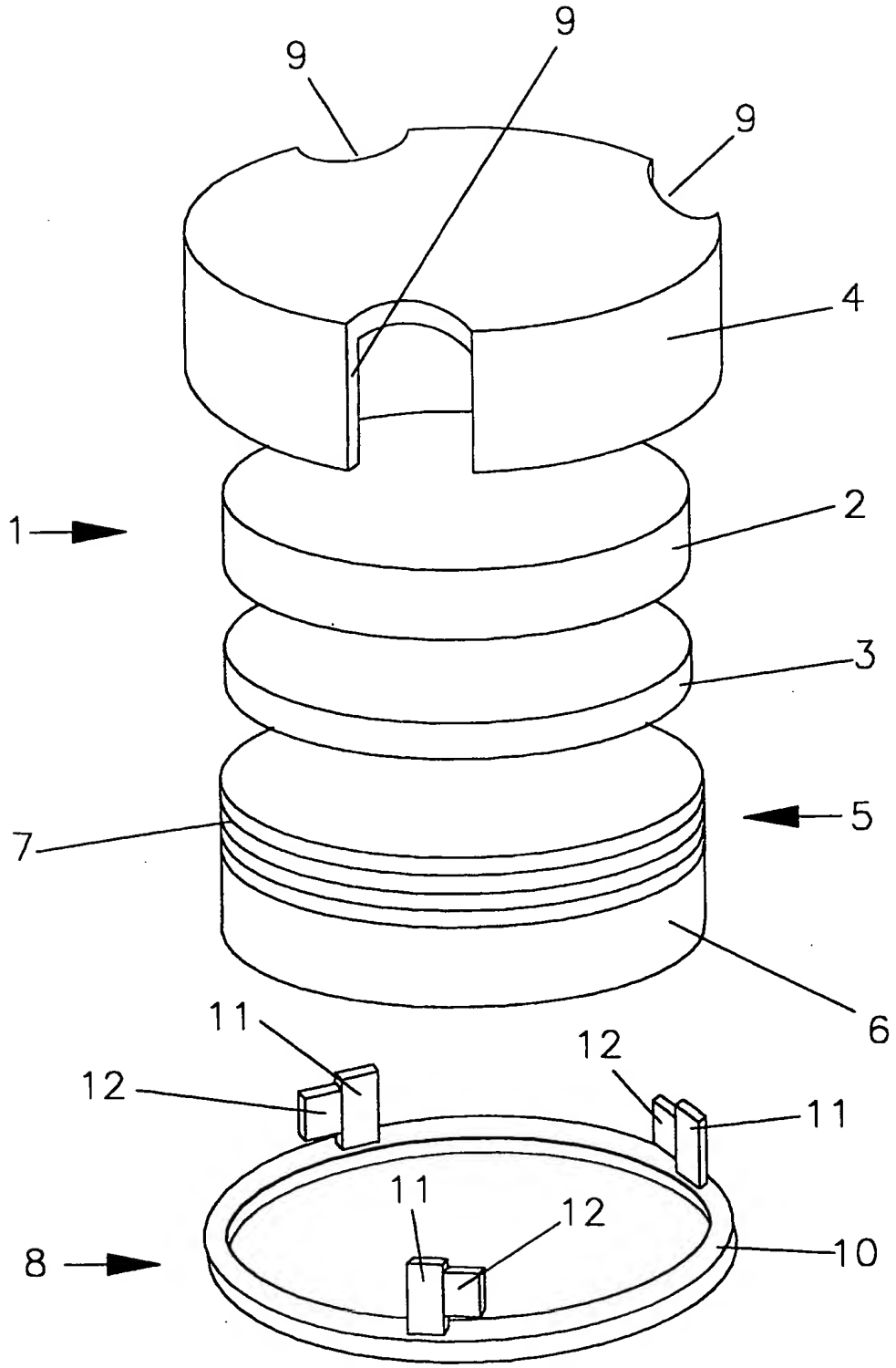


Figure 1a.

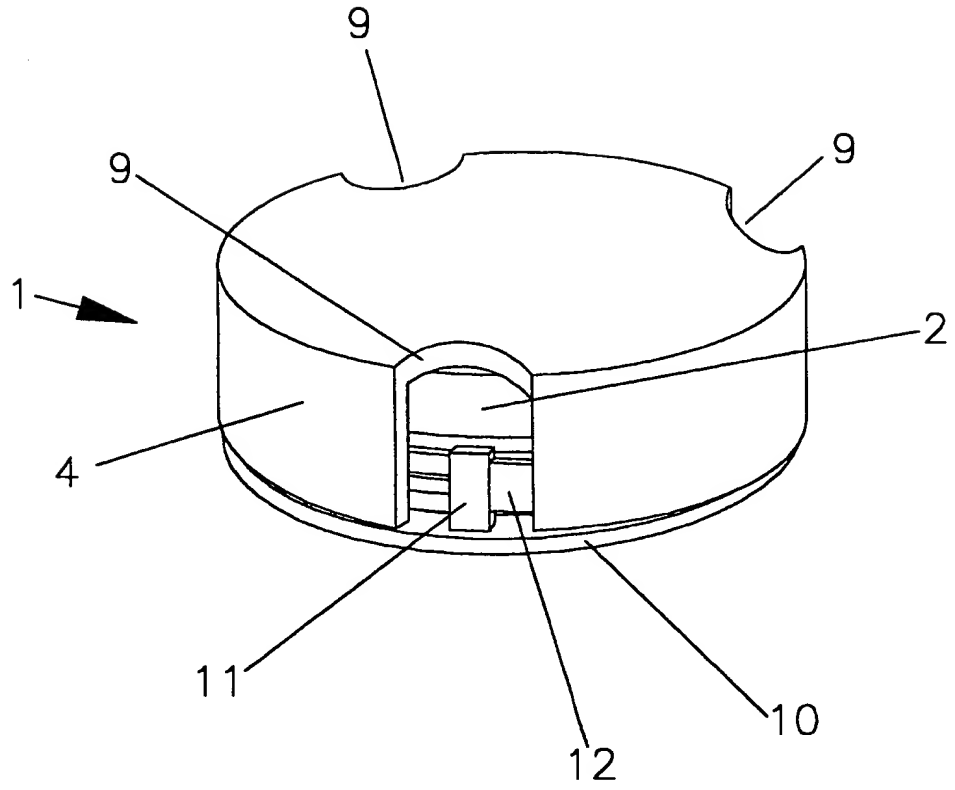


Figure 2

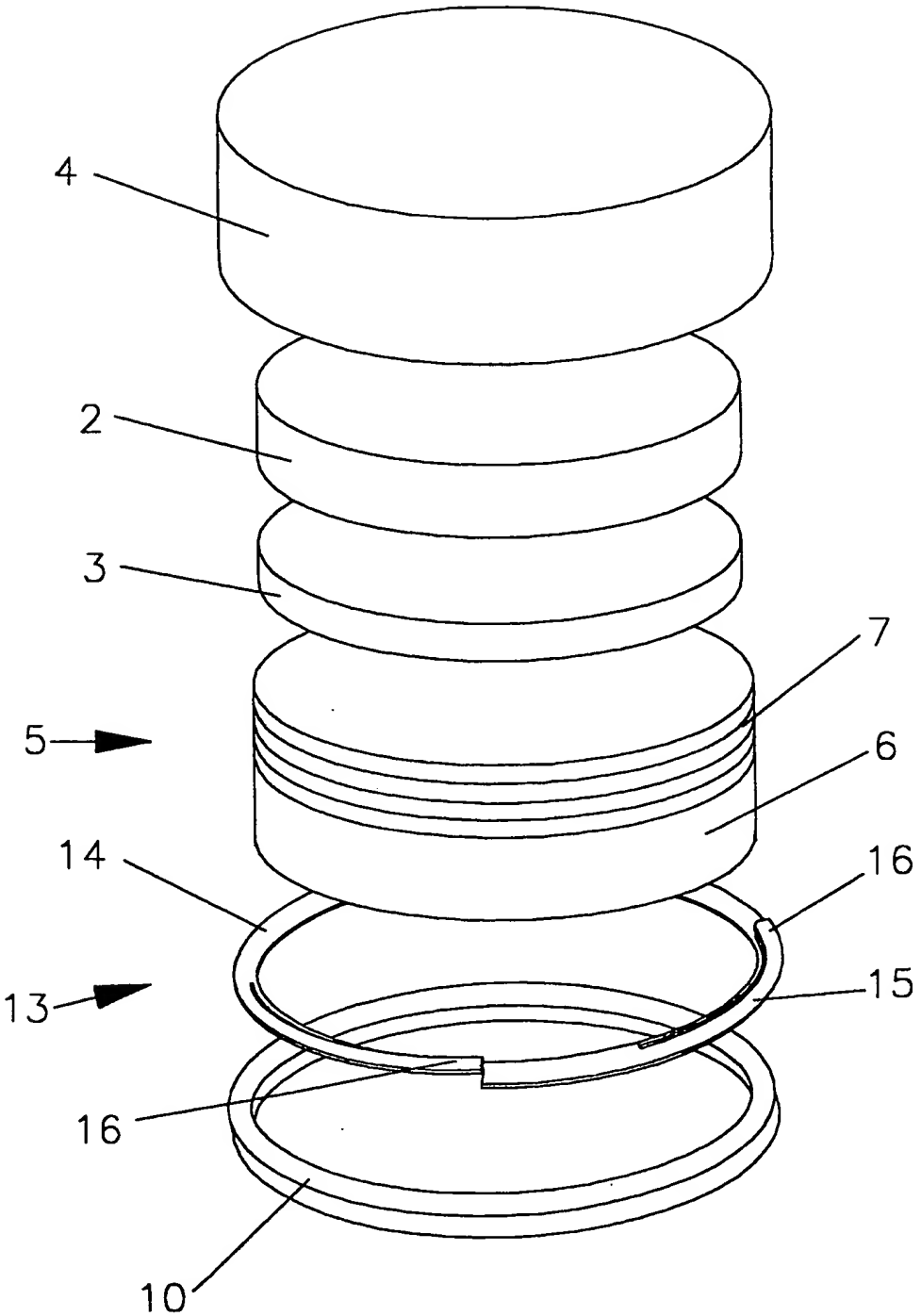


Figure 2a

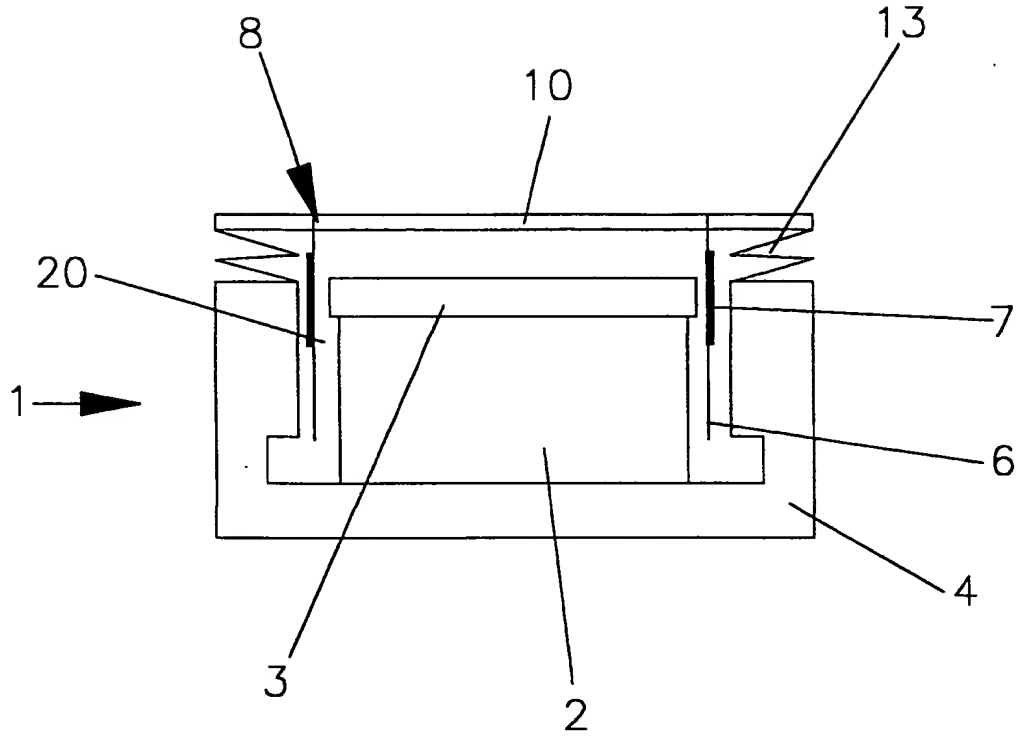


Figure 2b

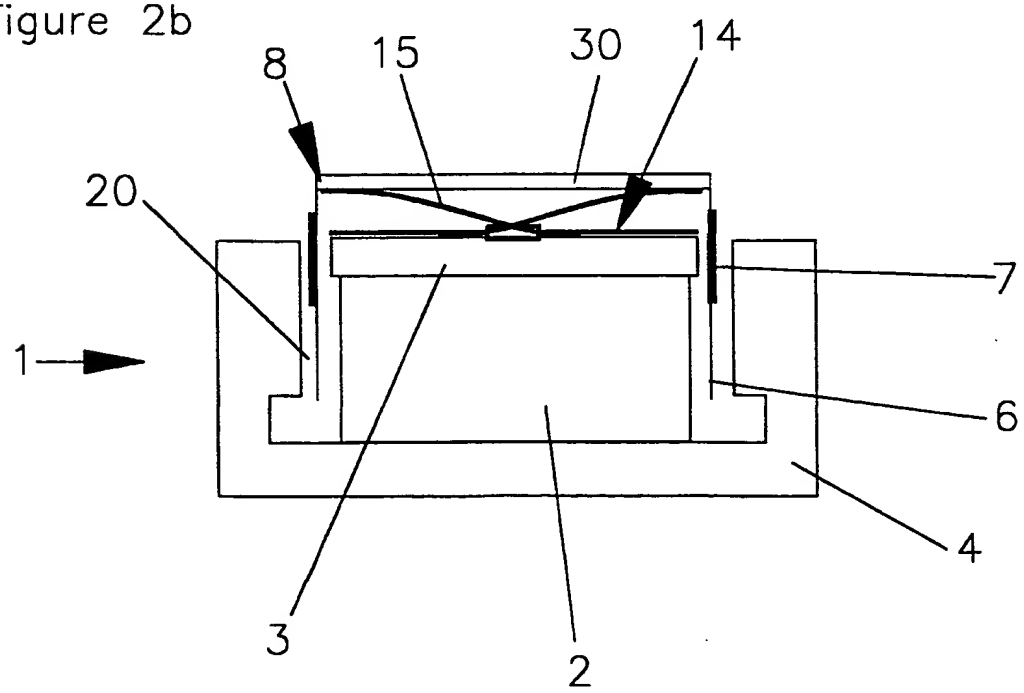


Figure 3

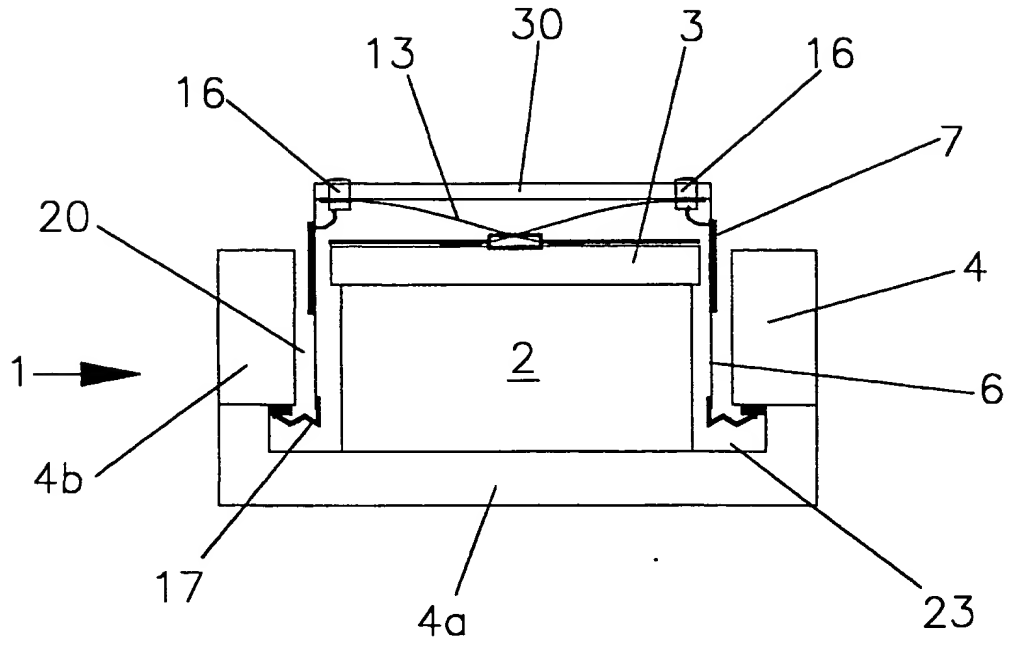


Figure 4

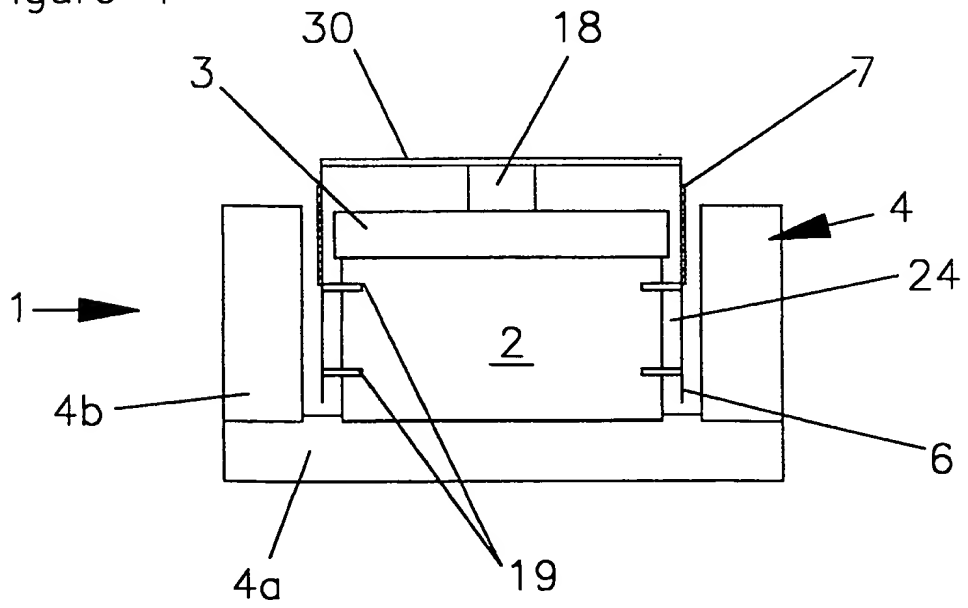


Figure 5

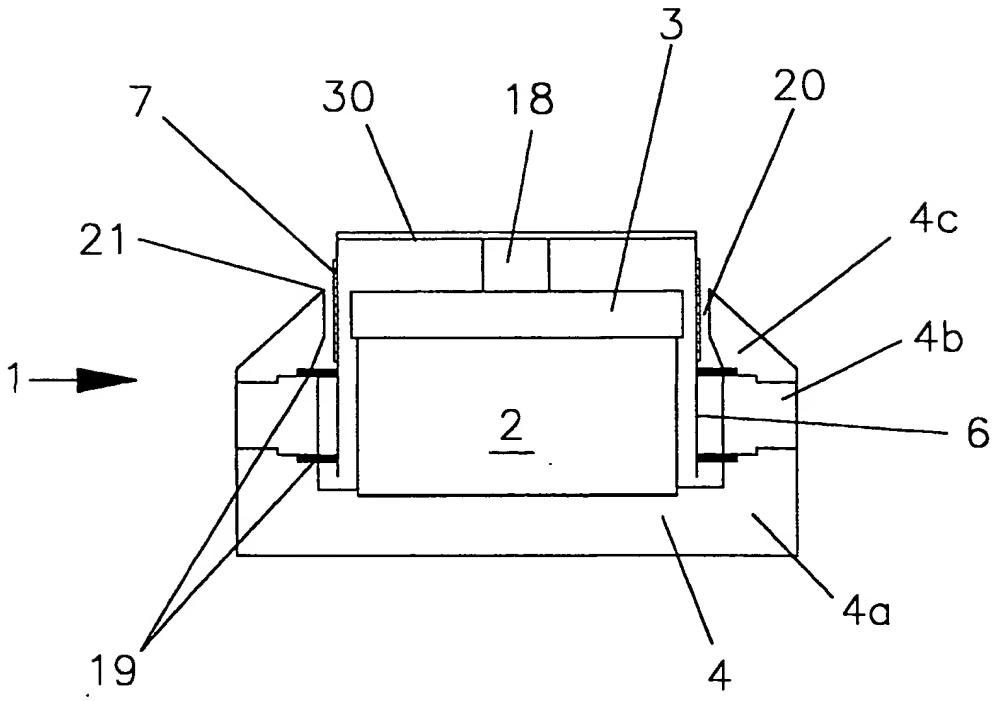


Figure 6

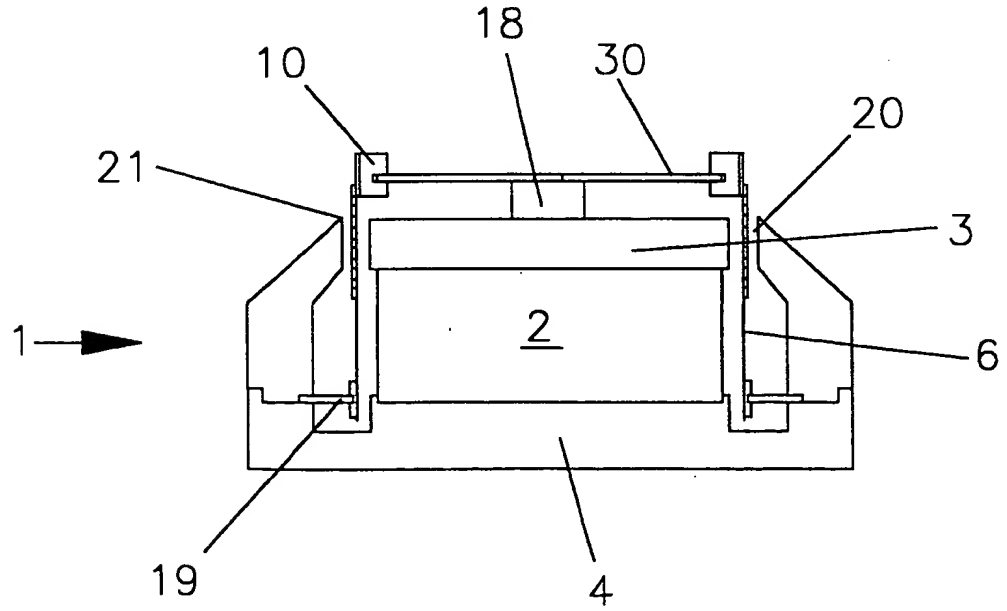
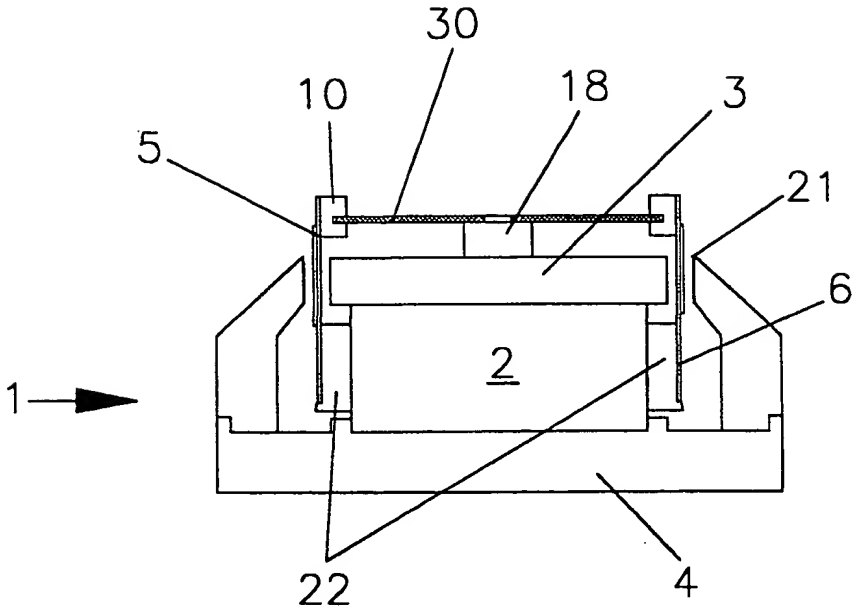


Figure 7



INTERNATIONAL SEARCH REPORT

In...national Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04R9/06 H04R9/04 H04R7/16

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 02012 A (NEW TRANSDUCERS LTD ;HARRIS NEIL (GB); MORECROFT DENIS (GB)) 14 January 1999 (1999-01-14)	1,12,19, 20
A	page 10, line 3 - line 15	2-11, 13-18

A	WO 97 09842 A (AZIMA HENRY ;HARRIS NEIL (GB); COLLOMS MARTIN (GB); VERITY GROUP P) 13 March 1997 (1997-03-13) cited in the application page 56, line 3 -page 57, line 9; figure 11	1-20

A	WO 98 34320 A (NEW TRANSDUCERS LTD ;AZIMA HENRY (GB); JARVIS EDWARD (GB); ROBERTS) 6 August 1998 (1998-08-06) page 2, line 10 -page 4, line 20; figures	1-20

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[X] Further documents are listed in the continuation of box C.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 52383 A (NEW TRANSDUCERS LTD ;HARRIS NEIL (GB); MORECROFT DENIS (GB)) 19 November 1998 (1998-11-19) page 9, line 9 - line 15; figure 6	1-20

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Information on patent family members

International Application No
PCT/GB 00/00333

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WO 9902012 A	14-01-1999	AU 8226798 A	25-01-1999
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